

Calculation and Estimation of Technical Losses in Transmission Networks

Abstract. Technical losses are caused by well-known physical electricity effects and cannot be effectively eliminated. However, they can be measured or calculated according to known line parameters. Distribution companies need the possibility to predict and estimate these losses as they are an important economic indicator, therefore they have fundamental importance. The paper deals with the possibilities of software developed and tested on real databases of measured losses provided by a distribution company.

Streszczenie. Straty techniczne spowodowane są przez znane zjawiska fizyczne i nie mogą być skutecznie wyeliminowane. Jednakże, mogą być mierzone lub obliczane według znanych parametrów linii. Spółki dystrybucyjne potrzebują możliwości przewidywania i szacowania tych strat, ponieważ są one ważnym wskaźnikiem ekonomicznym, dlatego mają fundamentalne znaczenie. Artykuł traktuje o możliwościach oprogramowania opracowanego i testowanego na rzeczywistych bazach danych pomiarów strat, dostarczonych przez firmy dystrybucyjne. (**Obliczanie i przewidywanie strat w liniach przesyłowych**)

Keywords: Calculation, Estimation, Technical losses, Transmission network.

Słowa kluczowe: obliczenia, oszacowanie, techniczne straty, sieć przesyłowa

Introduction

The implementation of new technologies and reduction of energy wasting in the points of its terminal consumption can bring substantial saving of electricity. The Czech Republic adopted the Energy Economy Act 406/2000 [1] which stipulates the rules for energy management with respect to sustainable development. It starts with the energy policy, continues with the National plan for economical management and use of renewable and secondary resources, and enumerates also some measures for increasing the economy of energy use.

One of the measures contained in the act is also the regulation 153/2001 on the calculation of technical losses which arise during the energy transmission and distribution (issued by the Ministry of Industry and Trade of the Czech Republic). It was the technical losses in their quantified form that were chosen as a benchmark for energy management.

We developed software which can bring a solution to the issue of estimation of technical losses on the VHV and HV lines. These losses embody a portion of electricity which is unused and they cause additional costs. They comprise:

- *Joule's losses* – arise due to the active resistance of the R conductors,
- *Corona losses* – caused by inefficient electrical insulation of conductors,
- *Leakage losses* – their cause is inefficient insulation against the potential of the earth.

Prediction of electricity consumption and technical losses

Both, the operation planning and the electricity purchase are structured in terms of time and divided into sections. This complies with the prediction horizons ranging from long-term (years), medium (trimesters, months), and short-term (weeks, days) to running (hours). The accuracy of predictions determines the economy of running the whole system. There is a direct relation of the prediction accuracy, operation control and its economical balance. The appropriate method of prediction is selected depending primarily on the purpose of its use [2].

To predict the technical losses on the lines of a distribution network, we need a database of measured values of technical losses (history), line parameters, database of P , Q , U , I measurements - history, and on-line data and estimation of electricity consumption. The most important factors which influence not only prediction of electricity consumption but also prediction of technical losses are

especially weather conditions (temperature, humidity, sunlight), untypical days and operational effects. [3].

The basic methods for estimation of electricity consumption are [4]:

- standard (statistical)
- knowledge-based models
- models using neural networks

It would be difficult to determine the most suitable model for the estimation - it depends on the quality and availability of input data. CEPS, plc uses prediction software based on the principle of both - the standard method and the method of neural networks.

Software for estimation of technical losses

The calculation methods and the principle of the software that we developed were described in [5]. The input data comprises off-line exports of the database measurements of voltage, currents, P and Q in 15-minute intervals (the output of TRIS system by CEPS) and parameters of lines. This programme enables computation of all the three kinds of losses for all the lines of Czech transmission network on the HV and VHV levels.

The outdoor temperatures affect the lines of transmission network and cause fluctuation of losses, which brings the need for software that would be able to calculate them. This article presents a description of a programme based on the methodology for prediction of Joule's losses that we developed.

Necessary prerequisites for estimation of predictive models

To estimate predictive models for different lines for given range of temperatures, these basic requirements and conditions must be fulfilled:

- standard load mode of transmission lines (basic configuration of the transmission system)
- available database of measured values of technical losses for required range of temperatures (data from the CEPS control system)
- interconnection of databases of outdoor temperatures and corresponding measured values of technical losses for different transmission lines.
- predictive curves of dependencies of technical losses on outdoor temperatures for different lines
- polynomial for calculation of technical losses for different lines (the input quantity is outdoor temperature)

Description of input databases for prediction

The input values must be in a required format so that the programme could compute and graphically display the course of Joule's losses depending on the outdoor temperature. To do this, measured values of Joule's losses for all the transmission lines (Table 1) and outdoor temperature data from the substations on the lines are required. These temperatures are average values measured on the terminal substations. The values of losses, outdoor temperatures and other measured data are saved in the control system for future use.

The structures of databases were designed at basic mode of the transmission system. Next, an input database containing the range of temperatures occurring within the Czech Republic had to be designed and corresponding values of Joule's losses matched with the temperatures. Measurements from January and February were used for low temperatures and July and August measurements for high temperatures. Table 2 shows a part of the input database. Table 3 shows the final database of outdoor temperatures in increasing sequence and corresponding values of Joule's losses. The database was created by interconnection of several input database.

Table 1. Database of measured Joule's losses on selected 400 kV lines

Date	Time	V400:P_Jlo	V401:P_Jlo	V402:P_Jlo	V403:P_Jlo
		[MW]	[MW]	[MW]	[MW]
1.7.2009	0:15:00	0.33	1.63	0.23	0.15
1.7.2009	0:30:00	0.33	1.51	0.21	0.08
1.7.2009	0:45:00	0.3	1.37	0.19	0.03
1.7.2009	1:00:00	0.28	1.41	0.23	0.09

Table 2. Input database of temperatures and Joule's losses

Date	Time	cPRN: T_outdoor	cNOS1: T_outdoor	average [°C]	V403:P_Jlo [MW]
		[°C]	[°C]		
27.1.2010	7:00	-14.49	-17.88	-16.19	0.73
27.1.2010	6:15	-14.49	-17.76	-16.13	0.64
27.1.2010	6:30	-14.49	-17.76	-16.13	0.69
25.1.2010	0:15	-13.20	-19.04	-16.12	0.68
27.1.2010	6:45	-14.49	-17.68	-16.09	0.74

Table 3. Input database in increasing sequence for generating the regressive function

Outdoor temperature [°C]	Joule's losses [MW]
-16	0.590
-15	0.538
↓	↓
+29	0.741
+30	0.826

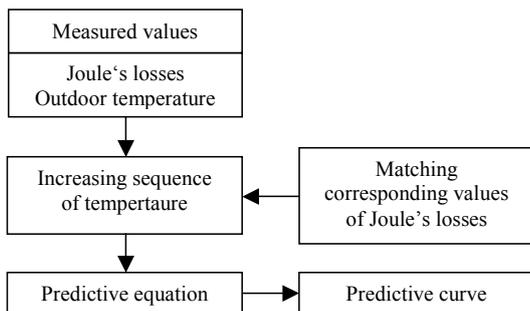


Fig.1. The sequence of design of predictive equation

Design of the predictive equation

On the basis of the assorted pairs of loss values and outdoor temperature values it was necessary to generate a corresponding predictive curve for each transmission line. The algorithm of its design is apparent from Fig. 1.

To determine the appropriate predictive model all we need are static and dynamic values of outdoor temperatures.

„Prediction of losses on transmission lines“ software

Our software is developed in Microsoft Visual Basic Professional because this environment allows easy and well-organized design of graphic user's interface [6]. It supports all the available advanced programming technologies and contains necessary modules for operation with Microsoft Office files and is fully operable in all the Microsoft systems.

Generally, our software is designed to allow intuitive operation, with logical sequencing with the lowest possible number of steps.

Software description

The main window is shown in Fig. 2. The left part of the status bar updates on the currently running operations - loading, saving data, computation. The middle part shows the file name with configuration if the file is loaded and different from configuration of possibly loaded file with results. And finally, the right part gives the name of a file with loaded or saved data. There are unrolled top 3 options from the main programme menu are in Fig. 3.

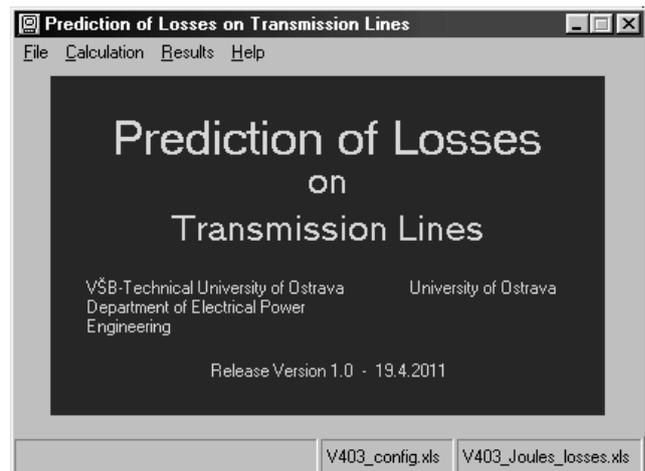


Fig.2. The main programme window with the welcome screen

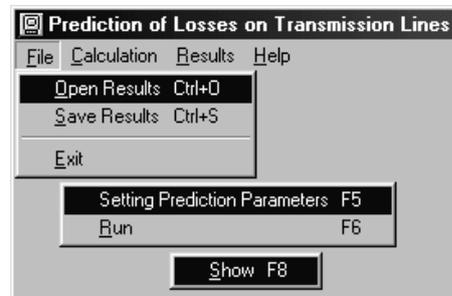


Fig.3. Unrolled options of the main menu

In the menu „File“ it is possible to load or save the calculation results. The actual parameters of the prediction of technical losses are to be set in “Calculation - Setting prediction parameters“. The procedure will be described further in another section.

Before calculating the prediction of technical losses, a required step and a range of temperature must be entered (Fig. 4). When the range is outside given intervals for predictive functions, the programme will give a notice. If the values are not corrected, the calculation is performed on the basis of a temperature curve with the temperature closest to the selected one.

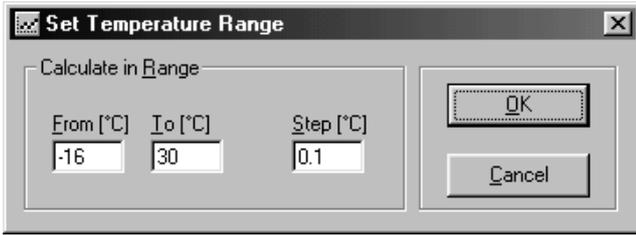


Fig.4. Outdoor range of temperature setup

After the calculation is completed, the results can be displayed in a table and a chart (Fig. 7). The curves of calculated losses can be shown in the range of temperature selected by a user. In the "File" menu the results can be saved in Excel. Having done so, the file with results displays two sheets. One sheet shows the configuration of calculation and the other shows the results. Hence, the file with results can be used also for configuration of another possible calculation.

If no configuration file has been previously loaded, the configuration sheet is loaded automatically. In such a case the middle window of the status bar stays blank because the used configuration corresponds with results, see Fig. 2.

If a configuration file has been previously loaded, a user is queried whether the older configuration file should be overwritten with the configuration contained in the results.

Predictive function

With the help of regressive analysis and using the processes databases, for each transmission line a predictive function of the fifth-order polynomial is generated. The software enables the required range of temperature to be divided in up to 5 partial intervals (Fig. 4) with allocated corresponding predictive curves. The required calculation of losses is ensured by selecting an option "Use this prediction" (Fig. 6). The final configuration can be saved in Excel.

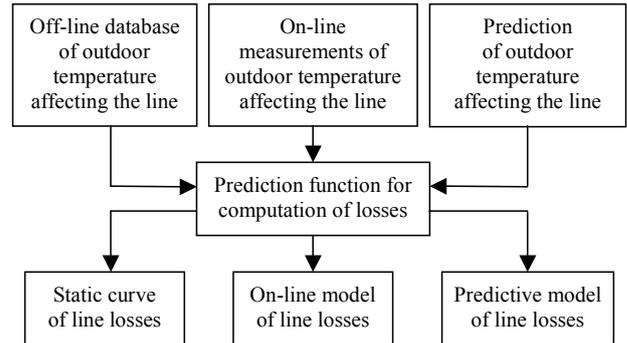


Fig.5. Predictive model of line losses

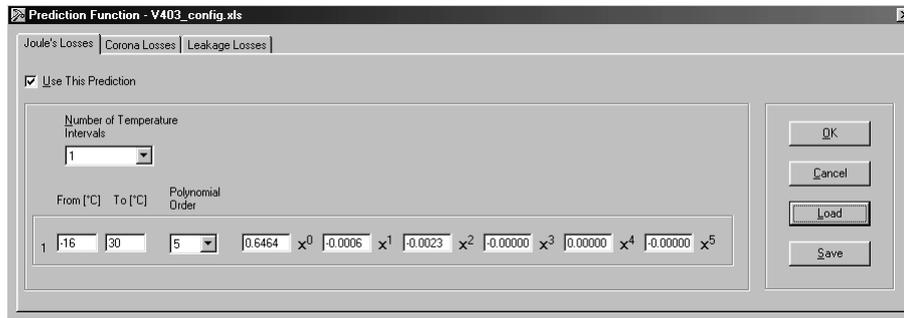


Fig.6. Predictive function setup

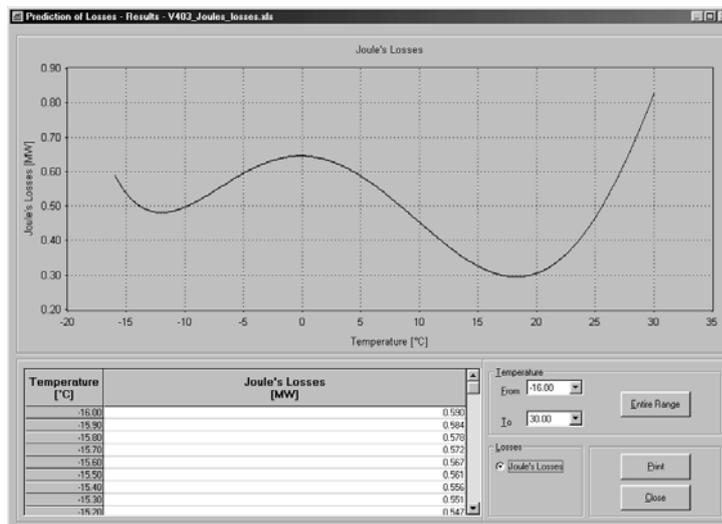


Fig.7. Prediction of Joule's losses - results

Field use of the software

The programme allows prediction of Joule's losses on the lines for which an applicable predictive function has been devised. Its principal importance is that it can be integrated into the control system of a company operating a transmission network.

A structural database contains outdoor temperature values from the substations on the lines arranged from the lowest to the highest (off-line processed database exports). Based on the knowledge of a predictive curve and a polynomial function, on-line models of losses on lines in actual time can be devised. The input quantity would be on-line temperature of a line, the evaluation element would be the polynomial of a predictive function and the output would be the relevant prediction curve.

Predictive model of line losses can be devised providing we have a power consumption predictive model and a corresponding temperature predictive model (Fig. 5).

Conclusion

The presented software is a logical follow-up of our work on the calculation of technical losses on transmission lines [3, 5]. On the basis of databases and generated predictive functions, for each transmission line only Joule's losses in given temperature intervals can be estimated currently. A complete database of predictive functions for VHV and HV lines is at our disposal. Using similar methodology, predictive functions for corona and leakage losses can be designed, for which our software is prepared. Their estimated values would be completed in the results table in Fig. 7.

The software was tested in CEPS, plc. and authorised as well. Provided we know the regressive function and have a structural database, we can acquire predictive models which can graphically display the Joule's losses in a preset range of temperature for selected transmission lines.

With on-line values of outdoor temperatures from the substations we could predict the course of Joule's losses on different transmission lines in current time.

Our software brings calculation results which are valuable and suitable especially for dispatching service and power lines operation planning. In the long run the possibility to control power losses in the transmission system has a practical meaning they are an important economical indicator for power distribution companies. Practically speaking, the fewer losses, the more efficiently power lines operate. Development of specialized software is, given the spread of IT in majority of fields, important and well-founded.

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